Root models to improve crop performance
From cell to field

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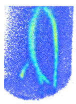
Introduction

Root architecture is the result of the sequence of expansion and lateral root initiation in meristems. Root architectures determine the efficiency of acquisition of resources, contributing to production of agriculture and competitive success in nature.

We are developing methods to predict the utilization of soil resources by crop plants. These methods include visualization, image analysis and data processing of live experiments. The data produced allows the development of new modeling principles and the construction of simulation software that can integrate the essential physical, genetic and physiological processes controlling plant development.

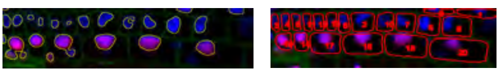
This research provides insight to the regulatory mechanisms of growth and development in complex environments and inform the selection of crop genotypes and management strategies that make best use of available resources.

Understanding the processes of development



Measuring root growth processes has traditionally been a laborious and descriptive task. We are developing computational-based techniques to improve the quality of data collected during root growth experiments. These methods allows to:

- observe and measure how root system architectures develop and interact with the soil;
- discover the mechanisms that control root growth in heterogeneous soil environment;
- obtain accurate and quantitative measurements of these processes to construct more reliable models.

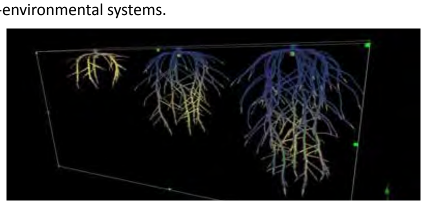


Segmentation of cell activity in root tissues using the BalloonSegmentation imageJ plugin

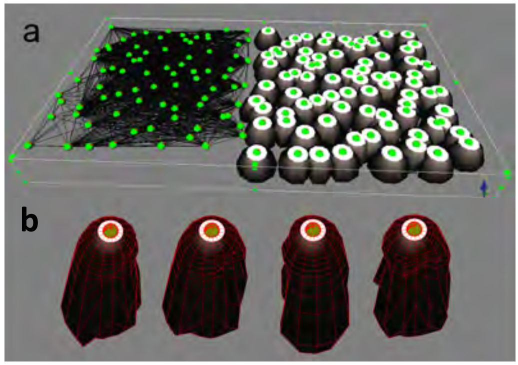
Improved models of root architectural development

Experimental research is providing large amounts of biological data with increasing accuracy and resolution. Making use of such complex information is difficult and mathematical methods are required to

- integrate experimental data into quantitative mechanisms in order to explain variations in crop performances observed in different environments and for different genotypes;
- develop new generations of models that can make more accurate predictions of root growth and uptake in complex and changing environments;
- build software tools that can simulate the flow of resources in complex agro-environmental systems.



Simulation of root system growth highlighting areas of maximum meristem density

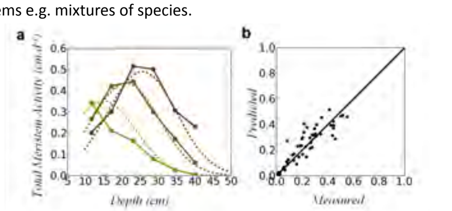


(a) deformable concept approach to predict competition in plant population. (b) root domains resulting from plant-plant interactions.

Predicting root growth in the field

Validated models are used to solve applied agronomic or environmental problems. We use different types of models to achieve these objectives:

- simplified models are being developed to predict root distribution in the soil.
- models that incorporate plant physiology, genetics and biophysics are used to identify crop traits that are most efficient in the capture of water and mineral nutrient.
- population models are used to assess the performance of agronomic systems e.g. mixtures of species.



The dynamics of root apical meristem distribution in the soil. a) traveling peak of meristems density. b) prediction vs measured meristem distribution in soil.

Conclusion

Understanding the numerous dynamic interactions between a plant 's innate developmental programme and resource availability in the environment is complex. We are developing quantitative approaches combining image acquisition, processing and modelling to reveal the nature of these interactions.

References

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